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HEAVY METAL POLLUTION IN THE MAIN RIVERS OF RWENZORI REGION, KASESE DISTRICT SOUTH-WESTERN UGANDA

Mukisa Wilber[a]*, Yatuha Jane[a], Andama Morgan[b], Aventino Kasangaki[c]
a. Department of Biology, Faculty of Science, Mbarara University of Science and Technology, Uganda.
b. Department of Biology, Faculty of Science, Muni University, Arua, Uganda.
c. Department of Biology, Faculty of Science, Busitema University, Tororo, Uganda.
Corresponding Author's Email: **mukisawilber@gmail.com**

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Abstract: Current study established heavy metal pollution of rivers Mubuku, Rwimi and Nyamwamba in Kasese district, Western Uganda. Their integrity is important because communities depend on them for water resources. No recent information is known on rivers' quality status yet traverse a densely populated area with agricultural activities and a history of copper/cobalt mining as heavy metals pose high health risks. The study was conducted from October 2019 to December 2019 and quantified levels of Cu, Zn, Pb and Co in water and fish to estimate the rivers quality. Water samples were randomly collected in sterilised bottle while fish samples were collected using non selective net method, dissected and dried to a constant mass. The total heavy metal load was determined using atomic absorption spectrophotometer. Results showed that, apart from Lead, the levels of Cu, Zn and Co in the waters were all within WHO limits except Co at one site on R. Nyamwamba with 0.233±0.009mg/L above the limit 0.05mg/L for drinking water. The overall mean for Pb was 0.030±0.006mg/L and 0.047±0.003mg/L at R. Nyamwamba, 0.053±0.003mg/L at R. Mubuku and 0.067±0.003mg/L at R. Rwimi, all above the WHO limit of 0.01mg/L. In fish tissues, Cu was within WHO limit; however, Pb and Zn were above limits (Pb, 2.0ppm; Zn, 100ppm) for fish. The average concentration for Pb was 29.05±4.85ppm, 69.23±9.25ppm and 32.33±5.93ppm at R. Nyamwamba, Rwimi and Mubuku respectively and for Zn, 115.05±8.12ppm, 117.47±8.65ppm and 118.69±8.79ppm at R. Nyamwamba, Rwimi and Mubuku respectively. Similarly, for all the three rivers, physico-chemical parameters; pH, temperature, electro-conductivity and dissolved oxygen were within the WHO limits but turbidity, 12.02±0.39NTU was above the limit of 5.0NTU. Therefore, there is need for management intervention to control further contamination of rivers with heavy metals and controlled use of water bodies as washing bays.

Keywords: Bioaccumulation; Mubuku; Nyamwamba; Rwimi, Water quality.

Postal Address: Department of Biology, Faculty of Science, Mbarara University of Science and Technology, Uganda. Tel: +256784862110

INTRODUCTION

Over the last 150 years, aquatic systems worldwide have been impacted by an array of anthropogenic factors (Falkenmark and Allard, 1991; Rahel, 2000; Dynesius and Nilsson, 2014). Human activities may alter the physical, chemical or biological processes associated with water resources and thus modify the resident biological community (Moyle *et al.,* 1992). Rivers and streams are very susceptible to contamination, because of their shallow aquifers (Adejuwon and Mbuk, 2011) and therefore unsafe. Despite the present efforts for pollution control in aquatic ecosystems, there are still cases of severe accumulation of industrial pollutants due to past activities. Furthermore, agricultural runoff, urban wastewater and bad operation of some treatment plants add pollutants and nutrients into aquatic systems (Benejam *et al.,* 2008, Khanna and Chugh, 2004). Water contamination deserves attention due to its hazardous effects to the environment, risk to human health and economic damages. Accurate and timely information on the quality of water is necessary for a number of reasons including public health management, policy and water quality improvement and utilization programmes. The physico-chemical characteristics of water play a significant role in predicting the quality of water for its best usage (Sharma and Saran, 2004; Sreenivasulu *et al.,* 2014) and the interactions of both the physical and chemical properties of water play a significant role in composition, distribution, abundance, movements and diversity of aquatic life forms (Mustapha and Omotoso, 2005). Heavy metal pollution is a widespread and serious form of aqua-contamination and has been implicated as the cause various human health related problems such as cancers, cardiovascular and neurological disease (UNECE, 1995 and Lawson, 2011). Heavy metal contaminants originate from multiple sources such as geological weathering, industrial effluents, domestic effluents, and agricultural fertilizers (Fo¨rstner and Wittmann, 1983). Studies on heavy metal pollution have been done in many rivers in the world (Fo¨rstner and Wittmann 1983; Moore, 1992 and Farag *et al.,* 1997). Fish for example, accumulate pollutants directly from contaminated water and indirectly through the food chain (Censi *et al.,* 2006 and Ashraf *et al.,* 2012) and the toxicity of these metals is due to biologically non-degradable and their tendency to accumulate in water, sediment and fish body (Gale *et al.,* 2004) and threaten the consumers (Terra *et al.,* 2008). In Uganda for example, R. Rwizi has been polluted due to Heavy Metal and Nutrient Loading into River by effluents from Mbarara Municipality (Egor *et al.,* 2017). Concentration of heavy metals have been established for Nyamwamba-Mubuku catchment area into lake George, (Andrew, 2007 and Katwesigye, 2014); but the heavy metal loads for the individual rivers and fish remains unknown. This study therefore aimed at assessing the concentrations of heavy metals in waters and fish as well as the physico-chemical parameters of rivers Mubuku, Nyamwamba and Rwimi in Albertine region western Uganda.

EXPERIMENTAL

The study was conducted from Rivers Mubuku (0° 17' 13.0128" N, 30° 6' 36.2232" E), Nyamwamba (31.872" N, 59' 24.9792" E) and Rwimi (0° 22' 22.8072" N, 12' 37.314" E) located in Mubuku-Nyamwamba catchment area in the Albertine rift region, Kasese district Western-Uganda (Figure 1) on the eastern part of Mt Rwenzori. The catchment area, estimated at approximately 33,487 Km^2 lies between Uganda and Democratic Republic of Congo (DRC) within the Albertine Rift Montane Eco-region of African Rift Lakes. All rivers originate from ranges of Rwenzori Mountain and meander south east draining into the swamps of Lake George in Queen Elizabeth National Park.

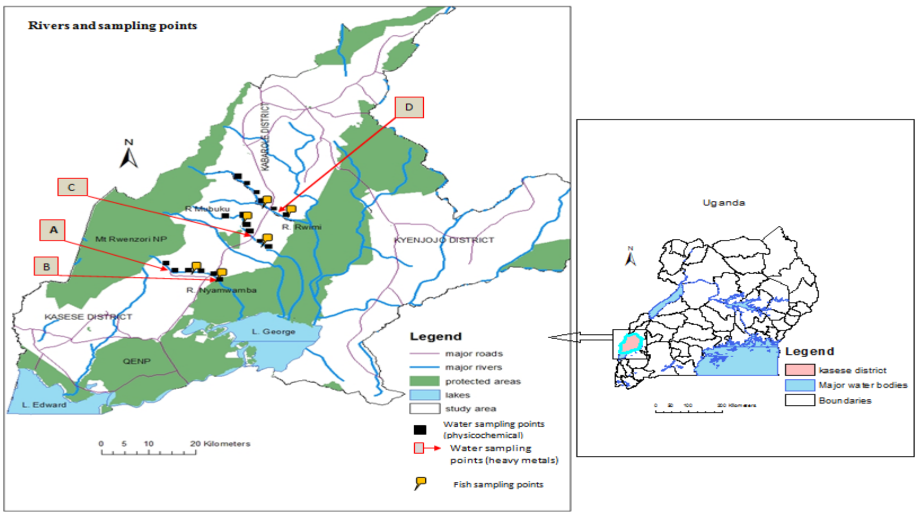


Figure 1. Study rivers from Kasese district

Sampling design and Sample collection

Water sampling sites on the rivers were randomly selected based on accessibility. For physico-chemical parameters, six different sites were established on each river (Figure 1). However, river Nyamwamba had two sites (A and B) for heavy metal determination in water, and A was purposively sampled, this was so because the river passes nearby previously abandoned site for copper/cobalt mines and Kilembe hospital. In this study, three of the six sites on each river were sampled in the morning (7**:**00am- 10**:**00am) and three in the evening (4**:**00pm-7**:**00pm) of the same day once a month in the period of October 2019 to December 2019. The sub-surface water was collected in triplicate and the water physico-chemical parameters, temperature (^{0}C), electrical conductivity (EC), pH, turbidity and dissolved oxygen (DO) were measured on spot and their averages were recorded (Rahmanian *et al.,* 2015). Water samples for heavy metal analysis were packed in a sterilized bottle (labelled separately), taken and kept frozen in a deep freezer. Fish samples were collected with the help of fishermen from each river during the month of October 2019 and December 2019 using non selective net method (mosquito net) with aim of not leaving any species un-sampled. The common fish was identified based on standard taxonomic keys (Mohsin and Ambak, 1991 and Kottelat *et al.,* 1993) as *Clarias liocephalus*. A total of 150 specimens of a common fish species (*Clarias liocephalus*) were captured during the period of this study (78 in October and 72 in December), out of these 36 fish specimens from rivers were randomly selected for determination of heavy metals in their tissues (body flesh and gills). For total content of metals (Cu, Zn, Pb, Co) in water and fish tissue samples were digested by the wet digestion method and analyzed by atomic absorption spectrophotometer (Akram *et al.,* 2014) from Makerere University Laboratory of Natural Science.

Statistical Analysis

Data was analysed using Microsoft Excel (version 20) and ANOVA in SPSS to obtain minimum, maximum, mean±SE of parameters, drawing of multiple graphs and to determine variations of parameters and heavy metals between rivers denoted by Fisher's (F) statistics with significant different means at a level of significance $p < 0.05$. A Pearson correlation test (r) was used to check the relationships between parameters and between rivers.

RESULTS AND DISCUSSION

Physico-chemical Parameters

In the present study, the mean pH values ranged from 5.72±0.04 to 6.67±0.03 in all rivers under study meaning that pH values were adequate for aquatic life (Chisty, 2002). The lowest pH of 5.870±0.06 was recorded in R. Mubuku and highest of 6.506±0.08 in R. Rwimi. The pH was an indication of acidic nature of the rivers. In any aquatic system pH is an important indicator of the water quality and the extent of pollution in the watershed areas (Kumar *et al.,* 2011; Singh, 2014). Earlier studies reported by Umavathi *et al.,* (2007) recorded that pH between 5 and 8.5 was best for aquatic life. Lower pH values of the rivers were attributed to increased microbial activities resulting into high decomposition rate of effluents as sewage and decomposable disposals releasing humic acid and carbon dioxide into water that lower the pH and also agricultural run-offs into the water bodies. Water temperature of the rivers during this study, ranged between 18.2^{o}C to 22.4^{o}C and therefore within the limits standards (Colman *et al.,* 1992; Boyd, 1998) according to WHO of 25^{o}C. This is very important, as many of the physical, biological and chemical characteristics of water bodies are directly affected by temperature (Trivedi and Goel, 1986). The temperature directly influences some of chemical reactions in aquatic ecosystems and its important physical parameter (Jakher and Rawat, 2003). Almost similar results were observed in studies conducted by Lehman, (2002) where he reported that the monthly mean fluctuations in temperature values ranged between 20 to 26^{0}C in Ishasha River and Lake Edward. Sharma *et al.,* (2000) observed that water temperature fluctuates between 21°C to 29°C during limnological studies of Udaipur lakes. The temperature variations are associated with wind force, inland water flow, influx of the rainwater and atmospheric temperature (Ramandham *et al.,* 1964).

The Electrical conductivity (EC) findings of this study indicate that relative number of ions being present in these rivers. The highest EC was recorded from river Rwimi (162.83±1.41 µS/cm) in comparison to river (146.50±1.93 µS/cm and 103.06±1.37 µS/cm) Nyamwamba and Mubuku respectively. This is due to the presence of ions in water. These salts typically include such cations and anions (Clean Water Team, 2004). The highest EC at Rwimi could be attributed to use of agricultural and fertilizers as well as discharge of domestic effluents related to the input of sewage water thus increasing the concentration of ions into water. More similar results were also reported by Patra *et al.,* (2010) of waters of Santragachi and Joypur Jheel, India. Das (2000) studied the limno-chemistry of some important reservoirs of Andhra Pradesh and observed that specific conductivity was in the range of 316 to 610 ms/cm. Kasangaki, (2019) reported that EC varied from 153.7 to 437.1µS/cm in the Bisina Opeta system and in the Mburo-Nakivale wetland system from 117.1µS/cm to 1423.5µS/cm. In water, DO measure the amount of oxygen in water thus vital to sustain aquatic life. During the present study the mean DO values ranged from 5.22±0.03 to 6.23±0.02mg/L in all rivers. River Mubuku registered the highest mean DO value 6.13±0.03mg/L and the lowest mean DO value at R. Nyamwamba 5.3±0.03mg/. All rivers had DO values at the lower limit as according to WHO permissible limit of 5.0mg/L. Higher DO can be due to relatively lower temperatures (Yadav *et al.,* 2013) leading to reduced metabolic activities and also increased photosynthetic reactions thus increasing the amount of DO in water. The low DO was attributed to waste discharges high in organic and oxidizable matter (Srivastava *et al.,* 2011; Singh *et al.,* 2012) resulting into increased microbial activity (Patnaik, 2005) favoured by higher temperatures, (Khanna *et al.,* 2012). Similar results were recorded by Chetana and Somasekhar, (1997) on riverine ecosystem of river Cauvery. Kasangaki, (2019) showed that DO in Bisina-Opeta and Mburo-Nakivale wetland system ranged from 3.03 to 7.23 mg/L and 6.3 to 9.9 mg/L respectively. During the present study, turbidity values were all above the standard permissible limits (5NTU) of WHO especially in rivers Rwimi and Nyamwamba. This could be attributed to presence of high organic matter pollution, other effluents, run-off with a high suspended matter content (Chapman, 1996). It could also be as a result of phytoplankton growth and agricultural run-offs high in sediment levels into river waters. Verma and Sharma, (2002) noted that turbidity affects water quality properties like light scattering, absorption properties and aesthetic appearance in water bodies. The results obtained were similar with the findings of Mathivaran *et al.,* (2005) at fish culture ponds at Viswanadhapuram in India. The variation in turbidity value was very similar to findings of Varunprasath and Daniel, (2010) of the freshwater river Cauvery, in India. Jeninah *et al.,* (2018) reported similar results from kakyeka upper stream in Mbarara-Municipality draining into river Rwizi with turbidity value of 11.4NTU.

Heavy Metal Pollution in Water

In this study, the average concentration of heavy metals in water was within the WHO guidelines, except Pb and Co at Nyamwamba, A. The highest mean for Cu (0.740±0.060 mg/L) was recorded at R. Nyamwamba, while the lowest value (0.010±0.000mg/L) was R. Rwimi. The high value of Cu at R. Nyamwamba could be due to the past activities of copper mining and tails that continuously lead copper into water, however all rivers had concentration below the WHO permissible guideline of 1.0 mg/L. WHO (1990, 1994). UNDP, (1998) reported that mean Cu level in water of Manzala Lake was 4.6-27.9ppm and 82% of the examined water samples exceeded the permissible limit of WHO. Cobalt at point R. Nyamwamba, A (mean, 0.233±0.009mg/L), was highest and minimum at rivers and not detected at R. Rwimi. The high level of cobalt at R. Nyamwamba could also be due to past mining activities of Cu/Co in the area. For lead (Pb), all sampling points had levels above the WHO permissible guideline of 0.01 mg/L in drinking water with the highest mean value from river Rwimi (0.067±0.003mg/L) and the lowest from river Nyamwamba (0.030±0.006mg/L). The elevated levels of Pb at the various sites are basically due to leakage of oil and gasoline from the vehicles being washed and also as a result of increased surface runoff from agricultural farms. Egor *et al.,* (2014) found that the average lead level in the river Rwizi waters was between 0.5-2.0μg/ml. In case of Zn, its levels were below the permissible level of 5.0 mg/L in the study rivers with the lowest value (0.010±0.00mg/L) recorded in rivers Mubuku and Rwimi while the highest value (0.076±0.003mg/L) was recorded from R. Nyamwamba, A (Nyamwamba river near the Kilembe mines headquarters and Kilembe hospital, near the former copper mining deposits). Zn is a naturally abundant element present as a common contaminant in agricultural, food wastes, manufacturing of pesticides as well as antifouling paints (Badr *et al.,* 2009). However higher results of zinc were found by (Egor *et al.,* 2014) in studies to determine heavy metal loading of river Rwizi Mbarara municipality.

Heavy Metal Pollution in Fish Tissues

Heavy metals are toxic aquatic pollutants whose uptake and accumulation in the aquatic biota beyond optimally safe limits could cause direct impacts on the aquatic food chain and eventually to man as a higher consumer (Rauf *et al.,* 2009). During this study, there were marked variations in the concentrations of heavy metals (Cu, Zn, Pb and Co) in flesh and gills of the *Clarias liocephalus* fish from river Mubuku, Nyamwamba and Rwimi (Table 3). The mean values of Cu were within the limit of WHO permissible limit in fish tissues though getting higher in fish tissues from R. Nyamwamba; however, the mean values of Pb, Co and Zn in fish tissues from all rivers were above the maximum allowable limit. According to (Rashed, 2001) the increasing rate of these elements is because they are extracted, concentrated and bio-accumulated with time from the water body. It can also be due to difference in the affinity of metals to fish tissues (Jezierska and Witeska, 2006), route of deposition (Ney and Vanhassel, 1983) and feeding habits (Yilmaz, 2009). *Clarias liocephalus* is a generalist feeder, having a wide selection of prey including aquatic dipteran larvae (Yatuha *et al.,* 2012). High level of Zn in fish tissues could be from use of fertilizers, sewage sludge, industrial wastes (Bradi, 2005). Also high levels of Zn in gills can also be due to absorption through the gills because they are in direct contact with contaminated water medium with a thin epithelial compared to body flesh (Bebianno *et al.,* 2004). Gills are pathways of metal ion exchange from water (Qadir and Malik, 2011) because gills have very wide surface area that fastens diffusion of metals rapidly (Dhaneesh *et al.,* 2012). Excessive Zn is detrimental to human health and can cause poising, diarrhea and fever (Chi *et al.,* 2007). The high mean Pb levels observed in fish from these rivers may be as result of elevated concentrations recorded in surface water (Nzeve *et al.,* 2014) especially R. Rwimi. It can also be attributed to washing of motor vehicles in rivers, poor disposal of lead containing materials like Lead batteries and use of agricultural pesticides containing Lead. Similar results reported by Ikem *et al.,* (2003), showed higher levels of trace elements such as Lead in gills relative to other tissues may be attributed to the affinity or strong coordination of metallothionein protein with these elements. Abou-Arab *et al.,* (1996) reported mean Pb residue in whole sardines and mackerel of 11.1ppm and 12.6ppm, respectively. In fish, Pb causes decreases in survival, growth, development, behaviour and metabolism, in addition to an increase in the formation of mucus (Eisler, 1988). Pb was also noted to causes renal failure and liver damage in humans (Salem *et al.,* 2000). The findings for Cu, Zn and Co in the fish organs in this study supports earlier findings by Jabeen *et al.,* (2012) where freshwater fish exhibited significant tendencies to bio-accumulate zinc in their organs, followed by the accumulation of these metals in the gills with statistically significant differences (Chezhian *et al.,* 2010). Results were similar to findings by, Yilmaz *et al.,* (2007) that in *Leuciscus cephalus* and *Lepornis gibbosus*, cobalt and copper accumulations in the gills were maximum, while least in the fish muscle.

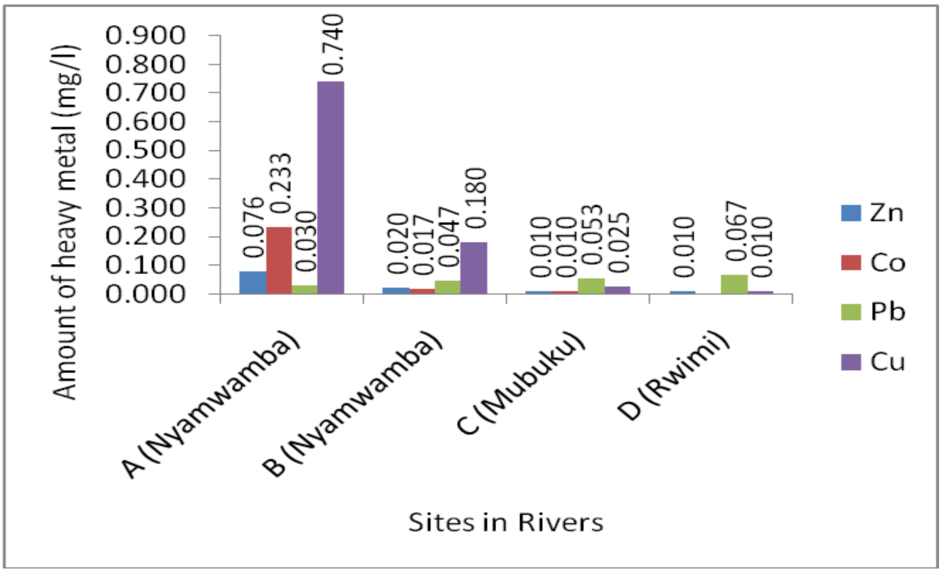
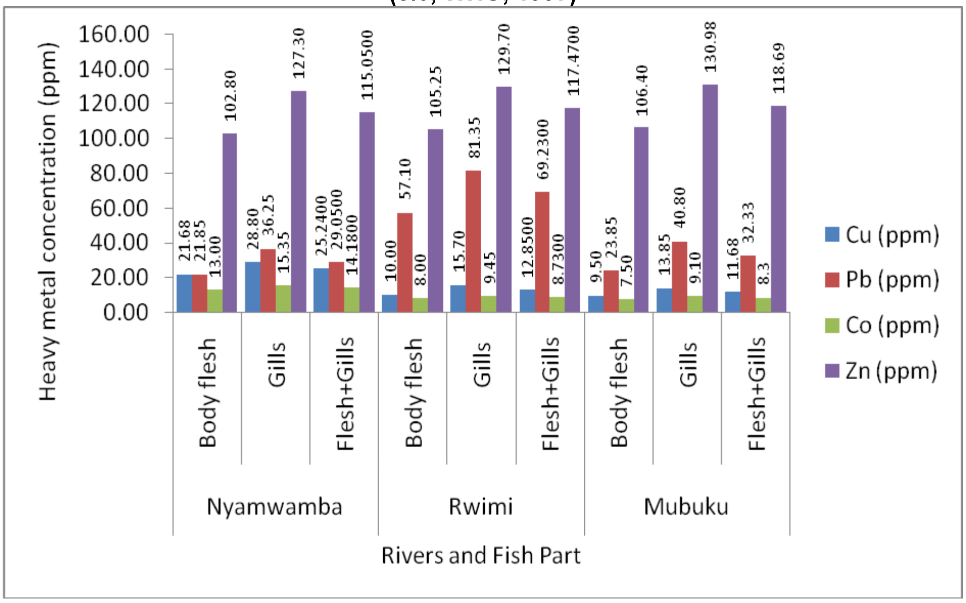


Figure 2. Heavy metal limits (mg/L), Cu (1.0, WHO, 1993), Pb (0.01, WHO, 1997), Co (0.05, WHO, 1989), Zn (5.0, WHO, 1997)



Heavy metal limits (ppm), WHO, 1995; Pb (2.0) Zn (100), Cu (30.0)

Figure 3. Heavy metal concentrations in the tissues of *Clarias liocephalus* fish from rivers, Mubuku, Nyamwamba and Rwimi

Table 1. General descriptive statistics of physico-chemical parameters for river Mubuku, Nyamwamba and Rwimi (October to December 2019)

Parameters	**River**	**Months**												**WHO acceptable range (1993)**
		October (n=6)			November (n=6)			December (n=6)			Overall (three months) (n=18)			
		Min	Max	Mean±SE	Min	Max	Mean±SE	Min	Max	Mean±SE	*Min*	*Max*	*Mean±SE*	
pH	Mub	5.60	6.00	5.74±0.07	5.58	5.81	5.72±0.04	5.96	6.30	6.15±0.05	*5.58*	*6.3*	*5.870±0.06*	6.5-8.5
	Nya	5.64	6.00	5.83±0.07	5.60	5.83	5.68±0.04	5.70	6.32	6.12±0.10	*5.6*	*6.32*	*5.874±0.06*	
	Rwi	6.43	6.85	6.69±0.07	5.85	6.66	6.16±0.13	6.56	6.81	6.67±0.03	*5.85*	*6.85*	*6.506±0.08*	
	Overall	5.60	6.85	6.09±0.11	5.58	6.66	5.85±0.07	5.70	6.81	6.31±0.07				
Temp (^{o}C)	Mub	19.50	20.60	20.13±0.17	18.80	19.50	19.27±0.10	19.90	20.30	20.12±0.06	18.8	20.6	19.84±0.12	25
	Nya	21.20	22.40	22.00±0.18	19.70	20.30	20.07±0.10	20.50	21.30	20.87±0.13	19.7	22.4	20.98±0.21	
	Rwi	19.80	20.80	20.33±0.16	18.20	19.20	18.52±0.15	19.20	19.70	19.48±0.08	18.2	20.8	19.44±0.19	
	Overall	19.50	22.40	20.82±0.22	18.20	20.30	19.28±0.17	19.20	21.30	20.16±0.15	-			
EC (µS/cm)	Mub	94.00	102.0	96.67±1.15	98.00	108.0	103.83±1.60	106.0	112.0	108.67±0.88	94	112	103.06±1.37	300^{c}
	Nya	135.0	140.0	137.33±0.84	140.0	152.0	146.83±1.70	150.0	159.0	155.33±1.36	135	159	146.50±1.93	
	Rwi	152.0	162.0	156.33±1.41	159.0	166.0	163.00±1.15	167.0	171.0	169.17±0.60	152	171	162.83±1.41	
	Overall	94.00	162.0	130.11±6.07	98.00	166.0	137.89±6.11	106.0	171.0	144.39±6.30				
Turb (NTU)	Mub	5.00	5.00	5.00±0.00	6.00	7.00	6.50±0.22	5.00	6.00	5.33±0.21	5	7	5.61±0.18	5
	Nya	11.00	12.00	11.67±0.21	14.00	15.00	14.67±0.21	13.00	14.00	13.50±0.22	11	15	13.28±0.32	
	Rwi	14.00	15.00	14.67±0.21	19.00	24.00	20.50±0.81	15.00	17.00	16.33±0.42	14	24	17.17±0.66	
	Overall	5.00	15.00	10.44±0.98	6.00	24.00	13.89±1.42	5.00	17.00	11.72±1.14				
D.O (mg/L)	Mub	6.15	6.30	6.23±0.02	5.95	6.15	6.04±0.04	5.99	6.27	6.12±0.05	5.95	6.3	6.13±0.03	5
	Nya	5.30	5.50	5.39±0.03	5.10	5.32	5.22±0.03	5.16	5.45	5.29±0.05	5.1	5.5	5.30±0.03	
	Rwi	5.65	5.86	5.72±0.03	5.48	5.67	5.58±0.03	5.59	5.71	5.63±0.02	5.48	5.86	5.64±0.02	
	Overall	5.30	6.30	5.78±0.08	5.10	6.15	5.61±0.08	5.16	6.27	5.68±0.09				

Mub-Mubuku; Nya-Nyamwamba; Rwi- Rwimi; Min-Minimum; Max-Maximum; SE-Standard error of mean; EC- electrical conductivity (µS/cm); D.O dissolved oxygen (mg/L); Turb – Turbidity (NTU), n=18 (overall in all sites) 300^{c} - WHO (2003)

Table 2. Heavy metal concentrations in the water (mg/L) at the various sites in rivers Mubuku, Nyamwamba and Rwimi for study period

Heavy metal (n=3)	Sites	A (Nyamwamba)	B (Nyamwamba)	C (Mubuku)	D (Rwimi)	F	p	WHO	Interpretation
Zn (mg/L)	Min	0.07	0.02	0.01	0.01	401.33	4.66E-9	5.0	Acceptable
	Max	0.08	0.02	0.01	0.01				
	Mean ±SE	0.076 ± 0.003	0.020 ± 0.000	0.010 ± 0.000	0.010 ± 0.000				
Co (mg/L)	Min	0.22	0.01	0.01	nd	423.07	2.65E-6	0.05	Acceptable except at A
	Max	0.25	0.02	0.01	nd				
	Mean ±SE	**0.233 ± 0.009**	0.017 ± 0.003	0.010 ±0.000	nd				
Pb (mg/L)	Min	0.02	0.04	0.05	0.06	13.94	0.002	0.01	**Unacceptable**
	Max	0.04	0.05	0.06	0.07				
	Mean ±SE	**0.030 ± 0.006**	**0.047 ± 0.003**	**0.053 ± 0.003**	**0.067 ± 0.003**				
Cu (mg/L)	Min	0.62	0.14	0.02	0.01	97.02	4.56E-6	1.0	Acceptable
	Max	0.80	0.21	0.03	0.01				
	Mean ±SE	0.740 ± 0.060	0.180 ± 0.021	0.025 ± 0.005	0.010 ± 0.000				

Min-Minimum; Max-Maximum; SE-Standard error of mean; A-Near Cu & Co Mines; B- after the bridge towards Entrance to QENP; C- Bathing, Washing of clothes, motorcycle washing; D- Car washing, sand mining, farm lands; nd = not detected; WHO standards; Zn (WHO, 1997); Co (WHO, 1989); Pb (WHO, 1997); Cu (WHO, 1993), n= number of replications, **Bold- Unacceptable**

Table 3.Heavy metal concentrations in the tissues of *Clarias liocephalus* sampled from rivers, Mubuku, Nyamwamba and Rwimi.

	River	**Nyamwamba**		**Rwimi**		**Mubuku**		**ANOVA Fish tissue (Flesh+Gills)**		**WHO Permissible Limit**	**Interpretation**
Heavy metal	Fish Tissue	Body flesh (n=2)	Gills (n=2)	Body flesh (n=2)	Gills (n=2)	Body flesh (n=2)	Gills (n=2)	F	p		
Cu (ppm)	Min	19.10	25.70	10.00	14.30	9.00	12.20			30.0	Acceptable
	Max	24.25	31.90	10.00	17.10	10.00	15.50				
	Mean ±SE	**21.68±2.57**	**28.8±3.10**	10.00±0.00	15.70±1.40	9.5±0.50	13.85±1.65	14.06	0.002		
Pb (ppm)	Min	20.50	30.30	44.80	73.10	20.30	33.40			2.0	Unacceptable
	Max	23.20	42.20	69.40	89.60	27.40	48.20				
	Mean ±SE	**21.85±1.35**	**36.25±5.95**	**57.10±12.30**	**81.35±8.25**	**23.85±3.55**	**40.80±7.40**	10.35	0.005		
Co (ppm)	Min	11.00	14.30	6.00	8.00	7.00	8.00			-	
	Max	15.00	16.40	10.00	10.90	8.00	10.20				
	Mean ±SE	13.00±2.00	15.35±1.05	8.00±2.00	9.45±1.45	7.50±0.50	9.10±1.10	10.88	0.004		
Zn (ppm)	Min	99.20	118.20	96.60	121.00	98.80	120.80			100	Unacceptable
	Max	106.40	136.40	113.89	138.40	114.00	141.15				
	Mean ±SE	**102.80±3.60**	**127.30±9.10**	**105.25±8.64**	**129.70±8.70**	**106.40±7.60**	**130.98±10.2**	0.05	0.95		

Min-Minimum; Max-Maximum; SE-Standard error of mean Bold – approaching the upper limit
WHO (1995) Bawuro et al., (2018) Dash (-) not detected, n- number of replications **Bold – above the limit**

CONCLUSION

The physico-chemical characteristics of these rivers would be acceptable and safe as according to WHO (1993, 2003). However, pH and turbidity at all rivers were unacceptable with turbidity above the maximum permissible limit in all rivers. The concentrations of heavy metals in all three rivers are still below the allowable limits set by WHO (1989, 1993 1997) except Lead (Pb). However, their levels in the river water are on the rise and in fish tissues they have surpassed the standard limits and therefore the quality of these rivers and their resources are unsafe which is a reflective of the growing anthropogenic pollution problem in the Albertine region and this poses a big threat to water resources as fresh water source for domestic and industrial use. Therefore, urgent management strategies for river watershed are required, treatment of effluent at the source before release into the water and practicing of environmentally friendly activities with use of phyto-plankton remediators is also recommended.

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